Cross comparison of two Analysis Tools for a Braceless Semi-Submersible Wind Turbine Versus Ocean Basin Test Results

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Abstract

In the frame of the IRPWIND project (Integrated Research Programme on Wind Energy), a benchmark is going on for comparing the numerical tools versus results obtained from ocean basin tests. A braceless semi-submersible wind turbine platform is considered herein. Real-time hybrid model (ReaTHM®) tests were done at 1:30 scale in MARINTEK's Ocean Basin in 2015 (http://windbench.net/marintek). The goal was to estimate the performance of a novel hybrid technique which avoids the use of a physical turbine for reproducing the aerodynamic loads. Instead, these being representative of the Northern North Sea wind conditions, were in real time calculated by a Blade Element Momentum (BEM) software and subsequently applied by a 5-degree-of-freedom actuators on the structure. The mooring system was typical of a three catenary mooring lines while the waves were produced by flapping mechanisms at basin's borders. The above mentioned system produced experimental results that were taken as reference for calibrating numerical hydrodynamic and structural models [1, 2, 3].

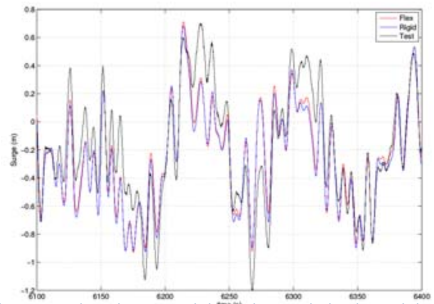
Objectives

In extreme weather conditions, the hull supporting the wind turbine may move significantly while the free surface of waves may break. The numerical simulations of such events are challenging and more research could advance better understanding the nonlinear dynamics associated to those events. On this basis a cross comparison between the commercial software such as SIMA based on a potential theory model with a CFD method as well as benchmarking against the experiment is attempted herein. The simulation focuses on the hull response to hydrodynamic and mooring forces. The main objective is to test the capabilities of engineering tools to predict the response of moored floating objects under extreme weather conditions. On the other hand, the implementation of high level CFD tools is investigated under the same conditions, although their implementation is expected to be quite challenging in terms of hydrodynamic modeling and computational resources required for such simulations.

Methods

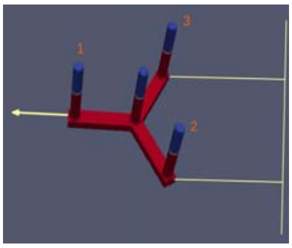
Two distinct methods are cross-compared in this work (http://windbench.net/models-offshore). On the one hand, SIMA (Advanced Analyses of Marine Operations and Floating Systems) is the state of the art numerical tools of MARINTEK for coupled/integrated simulations of floating offshore structures considering aero-hydro-servo-elastic formulations. It is about a nonlinear time-domain simulation tool which can capture all of the relevant hydrodynamic and aerodynamic loads, incorporate the control system actions and logic, and compute the structural response. On the other hand, HydroFoam is a combination of two open source tools forming a high fidelity analysis software for floating wind turbines. The first one is OpenFoam v.3.0.0 which predicts the hydrodynamic forces exerted on a moving floating through full CFD simulation, namely the Volume of Fluid method on moving meshes. This tool can be readily modified with the library waves2Foam (https://openfoamwiki.net/index.php/Contrib/waves2Foam) so that free surface water waves can be generated. In terms of the mooring system, OpenFoam supports only a simple spring-slider-dashpot model which is inadequate for simulating the concatenated, partially touching the floor chains used in the experiment. These can be simulated by making use of the open-source lumped-mass model line method. The open source code is the MoorDyn subroutine which is a stand-alone mooring simulator if fairlead motions are prescribed from a separate data file. This module is provided by the CAE tool FAST for horizontal wind turbines (https://nwtc.nrel.gov/FAST).

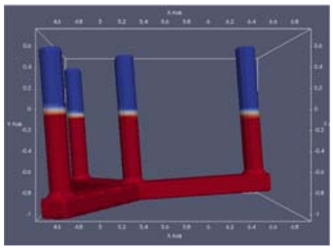
Results

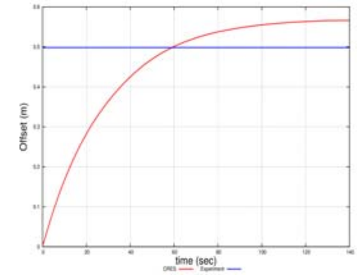


Braceless semisubmersible offshore wind turbine model, real-time hybrid model testing (ReaTHM) in Ocean basin facilities of MARINTEK October 2015) (left). The responses of the semisubmersible are compared for irregular wave-only load case, Test 2420, associated to normal operational conditions (right); refer to [1, 2, 3].

The results corresponds to significant wave height of 3.6 m and peak period of 10.2 s. Two sets of numerical modeling are presented, namely fully flexible tower-nacelle-rotor (Flex) and rigid modeling of tower-nacelle-rotor (Rigid). Both models agree very well for global motion responses and comparison of the numerical modeling in SIMA and test results are good, refer to [1, 2, 3].







Simulation with HydroFoam. Pull out tests . A constant excitation is applied as depicted in figure (left). A full time – defendant CFD simulation is implemented based on the Volume of Fluid method for two phase flows (air-water). Turbulence is accounted for through k-epsilon RANS model. The concatenated chain model accounts for internal axial stiffness and damping forces, weight and buoyancy forces, hydrodynamic forces from Morison's equation, and vertical spring-damper forces from contact with the seabed [4]. Upon application of the constant excitation force (see figure upper, left) the platform reaches a terminal position as depicted in figure (upper, right) having a realistic inclination. The offset from the initial position matches with the experimental value (see figure, lower) while the estimated maximum line tension matches within a 6% error with the experiment. The full pull out results are available at the following site: (http://windbench.net/pull-out-tests).

Conclusions

In the present work a cross comparison between an engineering tool (SIMA) and a high level CFD software (HydroFoam) is attempted. While the former has reached a certain degree of maturity, the latter is a promising method for simulations under extreme weather conditions where the application of potential theory is very challenging. Nevertheless, the computational overhead induced by the CFD method decelerates the development of the code. The preliminary results provided by a fully unsteady simulation on calm water with constant excitation seems promising.

References

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